[Proc. Roy. Soc. Victoria, 33 (N.S.), 1921].

Art. IV.—*The Relationships of the Sedimentary Rocks of the Gisborne District, Victoria.*

By W. J. HARRIS, B.A., and W. CRAWFORD.

[Read 8th July, 1920.]

I.—Area Dealt With.

The area dealt with in this paper is roughly rectangular, and includes about 170 square miles. It is bounded on the east by the Sunbury to Lancefield railway, on the north by Mount Macedon, on the west by Goodman's Creek, and on the south by a

line from Sunbury to Coimadai. It includes the areas represented by Quarter Sheets 6 SE., and 7 NW. of the Geological Survey of Victoria, and by portions of QSs. 6 SW. and 7 NE. The surveys for these sheets were carried out by C. D. Aplin and N. Taylor, under the direction of Dr. A. R. C. Selwyn. Graptolites collected by the Survey parties were described and figured by Sir F. McCoy.[1] In an area so extensive, and in parts practically unsurveyed, there is room for division of opinion on geological questions, and our opportunities have not permitted as thorough an examination of all portions of the district as we could wish. For sufficient reasons, we have excluded from this paper all detailed consideration of igneous rocks. The boundaries shown on the accompanying Sketch Map have been copied in the main from the Quarter Sheets, or from the map of Messrs. Skeats and Summers.[2] We ourselves have made few alterations in the actual boundaries, though we differ from the earlier maps in our classification of the rocks shown.

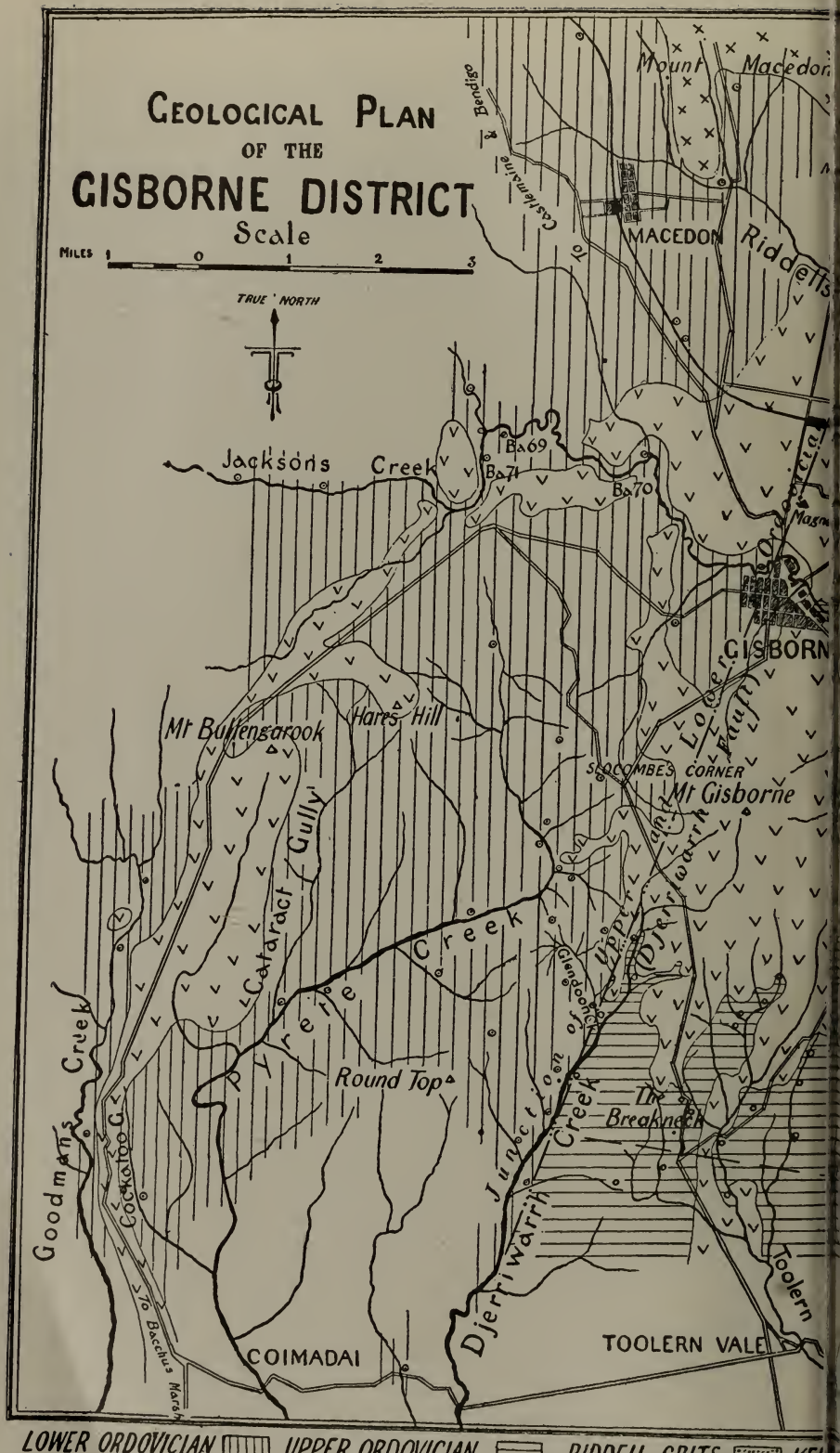
II.—Previous Literature.

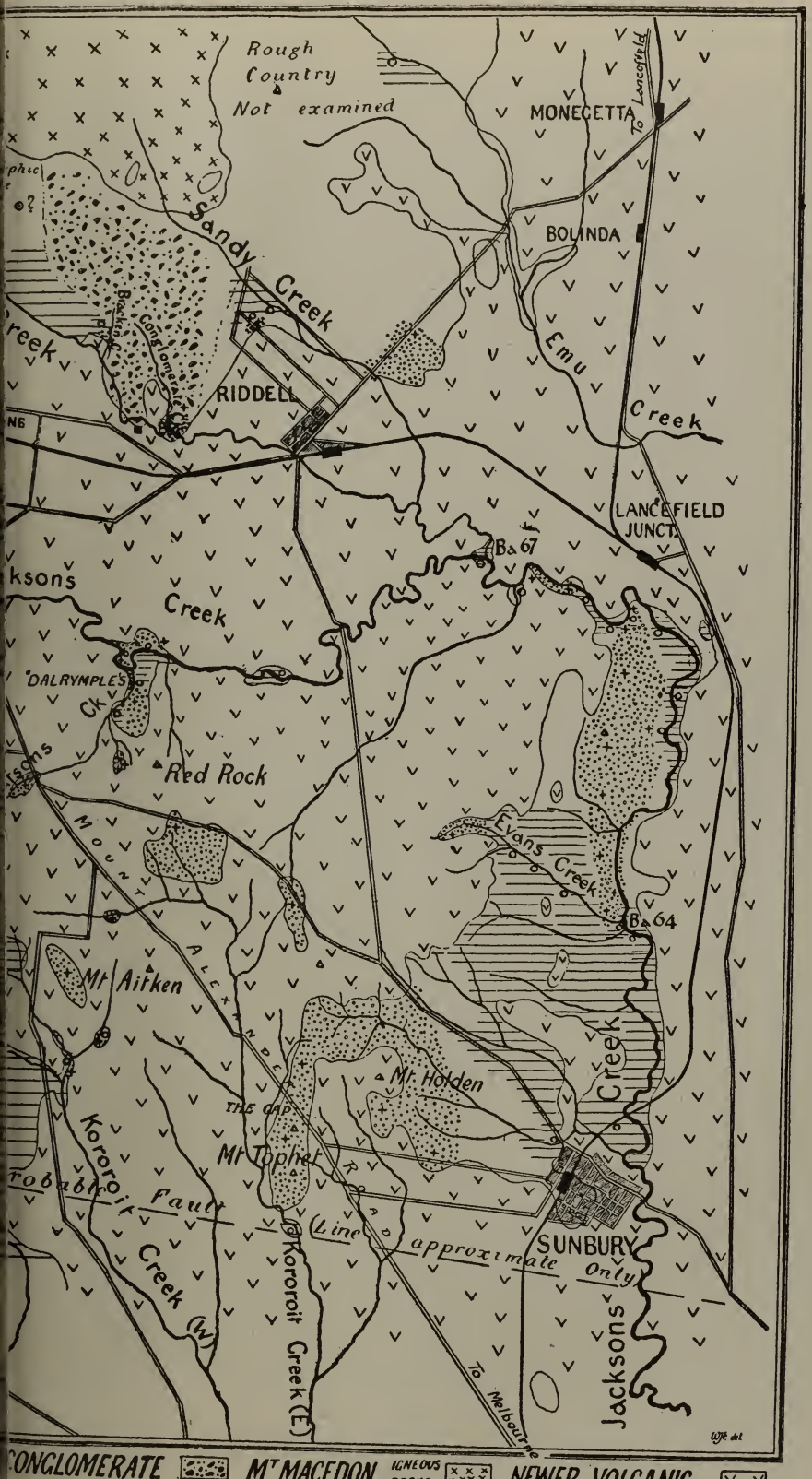
During the last half century the area seems to have received scant attention geologically, except in so far as the northern portion has been included in an account of Mount Macedon by Messrs. Skeats and Summers.[2] While our investigations were in progress the Defence Department published two contour maps covering the southern portion of the area. Dr. C. Fenner's paper on the Werribee River,[3] though mainly concerned with the area to the south and west, is also of interest. Dr. T. S. Hall[4] identified graptolites from the Coimadai side of the district.

III.—Nomenclature.

As in many other parts of Victoria, the local names of streams and topographical features in general do not always agree with those shown on the maps, nor are the maps always in agreement with each other. On the Quarter Sheets the main stream of the district is shown as the Saltwater or Macedon River; McCoy[5] refers to it as the Saltwater; the military sketch map of the Macedon and Lancefield District marks it the Macedon River;

1. 1.
2. 4.
3. 5.
4. 6.
5. 1, Dec. 1, pp. 9, 14.


GEOLOGICAL PLAN
OF THE
GISBORNE DISTRICT
Scale
MILES 1 0 1 2 3
TRUE NORTH
Bendigo
Castlemaine
To
Mount Macedon
MACEDON
Riddells
Jacksons Creek
Ba69
Ba71
Ba70
GISBORN
Mt Bullengarook
Hares Hill
SLOCOMBE'S CORNER
Mt Gisborne
Lerderderg
Cataract Gully
Spyrie Creek
Glengower
Upper Djerriwarrh
Round Top
The Breakneck
Junction of Djerriwarrh Creek
Goodmans Creek
Cockatoo G.
To Bacchus Marsh
COIMADAI
TOOLERN VALE
Toolern
LOWER ORDOVICIAN
UPPER ORDOVICIAN
RIDDELL GRITS
FOSSILS


Rough Country
Not examined
MONEGETTA
To Lancefield
BOLINDA
Sandy Creek
Emu Creek
RIDDELL
LANCEFIELD JUNCT
B.67
Creek
DALRYMPLES Ck
Red Rock
Evans Creek
B.64
Mt Aitken
Mt. Holden
Mt Topher
Kororoit Fault
Kororoit Creek (E)
Kororoit Creek (W)
(Line approximate Only)
SUNBURY
Jacksons Creek
To Melbourne
CONGLOMERATE
Mt MACEDON IGNEOUS ROCKS
NEWER VOLCANIC

above Gisborne it is often called the Gisborne Creek, and below Sunbury, the Jackson's Creek, which is the name adopted by the Military Survey for its contoured plan, and will be the name used throughout this paper.

The Pyrete Creek is unnamed on the Quarter Sheets, on the Geological Survey Map of Victoria, and on the county plan of Bourke. On this last plan its lower course is shown as the Coimadai Creek, which is the local name for that portion of it. On the Military Survey map the name is spelled Pyrett. On the county plan a small eastern tributary of the Djerriwarrh is called the Parrait.

On the Quarter Sheets, east of the Gisborne-Melton Road we have, in order from west to east, the Toolam Toolern, Yangardook and Kororoit Creeks. On the county plan the first becomes the Toolerrn Toolerrne! On the military map it is abbreviated to Toolern Creek, its local name, while the Yangardook becomes Condon's Creek.

Broadbent's "Holiday Map," which, though unofficial, is of great help in the field, is very inaccurate as regards names in the Pyrete district. The upper Pyrete is not marked; the course of Goodman's Creek and neighbouring streams, apparently copied from the defective county plan, are incorrect. Goodman's Creek should flow south; the stream shown as the Cockatoo is known locally as Cataract Gully, Cockatoo Gully being a smaller gully nearer Coimadai; while the name Durdiwarrh, borrowed from the Steiglitz district, is misapplied to the Djerriwarrh, and the Toolern Creek is called the Toolam Toolam.

On QS. 6 S.E. the fossil locality at the mouth of Riddell's Creek is shown as Ba 68, instead of Ba 67. McCoy[6] in referring to the same locality calls it "Ba 67, Section 24, Parish of Bulla." The outcrop in Section 24, Bulla, is Ba 68.[7]

IV.—Classification of Rocks in the Area.

(a) Geological Survey Classification.

From the account of previous work it will be seen that the Geological Survey Quarter Sheets are geologically the chief guide for the greater part of the district, though we have availed ourselves of the Memoir of Messrs. Skeat and Summers in our work on the Macedon section, while Dr. Fenner's paper has also been of use.

6. 1, Dec. 1, pp. 10, 11, 12.
7. Communicated by Mr. F. Chapman, A.L.S., National Museum.

Within the mapped area the Quarter Sheets show the following rocks, Macedon igneous rocks excluded.

(i.) Alluvium.
(ii) Upper Volcanic.
(iii.) Newer and Older Pliocene.
(iv.) Oolitic.
(v.) Lower Silurian.

Of these the Lower Silurian would now be termed Ordovician. The so-called Oolitic is the Kerrie Conglomerate.

(b) Proposed Revised Classification.

We propose the following classification:—

(i.) Alluvium.
(ii.) Newer Volcanic.
(iii.) Pre-Newer Volcanic Gravels.
(iv.) Kerrie Conglomerate.
(v.) Riddell Grits.
(vi.) Upper Ordovician. Shales, slates and sandstones.
(vii.) Lower Ordovician. „ „ „ „

This classification differs from the earlier one in its division of the Ordovician, in distinguishing the Riddell Grits as a distinct geological phase, and in specifically indicating the Kerrie Conglomerate.

V.—Physiographical Features.

Physiographically the district may be divided into two areas, western and eastern. The division line is the Djerriwarrh fault line running south from Gisborne to the Djerriwarrh Creek, the valley of which follows it for some distance. This fault determines the boundary of Upper and Lower Ordovician. Lower Ordovician rocks predominate in the western area, but are not found in the eastern, which is for the most part covered with basalt of the Newer Volcanic flows. Throughout this eastern area are more or less isolated exposures of palaeozoic sedimentary rocks, of which the oldest are Upper Ordovician. Upper Ordovician rocks do not appear west of the fault line. (Fig. 3).

The stream development of the western area has been profoundly modified by the Djerriwarrh Fault, and the lava flows from Mount Bullengarook and Hare's Hill. As showing the pre-Newer Volcanic age of the Djerriwarrh Fault, it may be noted that it in no place dislocates the basalt, and, secondly, that in parts all trace of it has been obliterated by the infilling

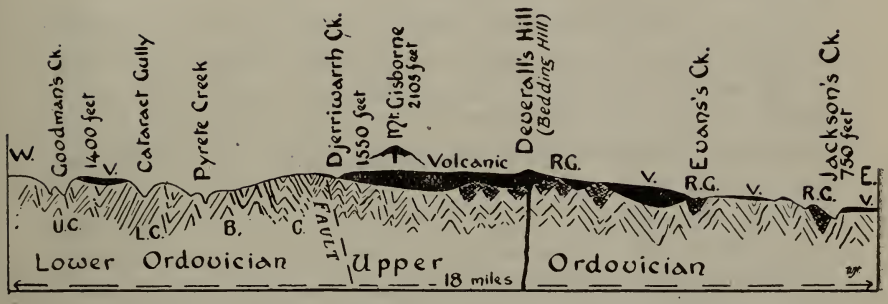


Fig 1 Section across central part of district, bearing E.15°N. (mag.) Diagrammatic.

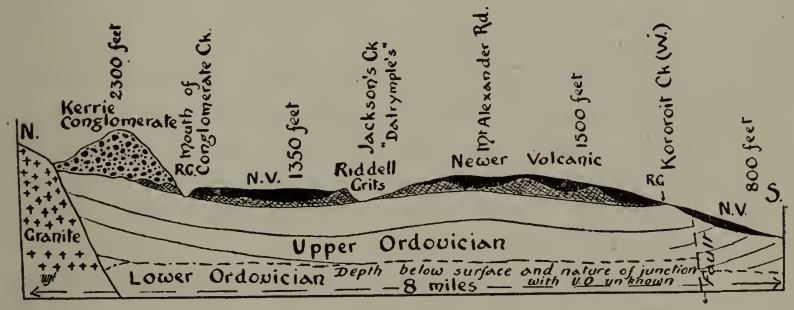


Fig 2 Section — Sandy Creek to Toolern Vale, bearing N.3°E. (Diag.)

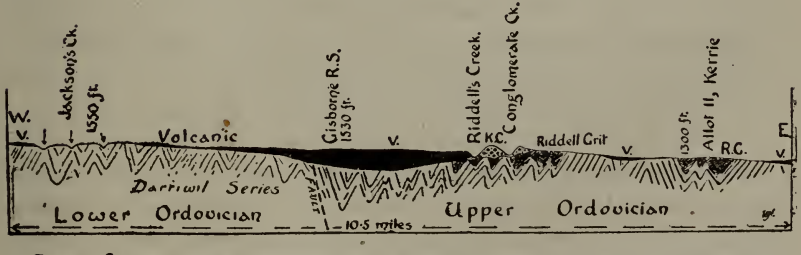


Fig 3 Section across northern part of district, bearing E.10°N., (mag.) — Diagrammatic.

by basalt of valleys cut back from its scarp. Such infilled valleys occur north-west of Gisborne, near Slocombe's Corner, and at the Glendoon Spur. (QSs. 6 SW. and 7 NW.)

There is evidence that the Macedon platform was a definite geological feature at the time of the faulting, the throw seeming to diminish as it approaches Mount Macedon, while north of the Mount no dislocation is shown by the palaeozoic rocks, Lower Ordovician (Darriwil) graptolites being found at Woodend, east of Carlsruhe, and at Newham.

While the evidence for the re-construction of obliterated physiography must of necessity be more or less inconclusive, it is probable that the history of the western area is as under:—

(a) Previous to the Djerriwarrh Fault a stream—the "ancient Bullengarook" of Messrs. Officer and Hogg —rose north of Gisborne, and flowed south-west towards Bacchus Marsh.

(b) The Djerriwarrh Fault reversed the direction of the portion of this stream west of Gisborne, so that a new local watershed was formed near the present Mount Bullengarook.

(c) On this Divide volcanic activity built up Mount Bullengarook and Hare's Hill, which sent lava flows down the valleys to the north-east and south-west, forming the ridge now followed by the Gisborne-Bacchus Marsh Road, and also the outliers along upper Jackson's Creek.

(d) Erosion in post-Newer Volcanic times developed the present stream system.

Further details will be given when treating of the eastern area. It may be noted that the northern and north-eastern slopes of the Bullengarook area are gradual, and are covered by widespread gravel deposits. The southern slopes, the Pyrete Ranges, consist of steep hills often 1600 feet above sea level, sloping steeply to valleys 200 or 300 feet below. Gravels are absent. The highest bed rock in the area is around Mount Bullengarook. Sediments outcropping on the Bacchus Marsh road on the north-western slope of the mountain are 1900 feet above sea level.

The development of the drainage system of the eastern area is typically what may be expected on an extensive lava flow which has covered and obliterated the earlier river valleys. The higher portions of the watersheds project as hills, or have been exposed by vertical erosion. The position of these inliers indicates that

the pre-Newer Volcanic streams trended southerly, and were divided by north and south water partings.

Following the main stream—Jackson's Creek—northwards from Sunbury, we find that it has cut down on to Upper Ordovician shales and Riddell Grits. From Lancefield Junction westwards there are alternating outcrops of Newer Basalt and palaeozoic rocks—Upper Ordovician and Riddell Grits, the basalt representing the old valleys and the sediments the intervening watersheds. There is evidence that the older valleys were in a mature state, and pre-Newer Volcanic gravels rest on their slopes in many places. Some of the earlier streams would naturally be larger than others, and in particular two large streams indicated by the wider stretch of basalt seem to have converged from N.E. and N.W. to a confluence near Mount Aitken, and then to have trended south between Mount Tophet and the Western Kororoit Creek. (See Fig. 2.)

Proceeding west to the Djerriwarrh Fault, the most important change, the reversal of the Upper Bullengarook to form portion of Jackson's Creek, has already been referred to. The waters of this reversed stream, and of its original source north of Gisborne R.S., would flow to the south through the Mount Aitken Gap. The Upper Pyrete, with its boat hook tributaries, probably flowed north at this period, and added its waters to the same stream. The main laterals of the Bullengarook lava field were Goodman's Creek and Cataract Gully. Goodman's Creek had scope for development, flowing over homogeneous rocks, but Cataract Gully found its activity limited by the resistent basalts of Mount Bullengarook and Hare's Hill. An eastern tributary better situated for erosion developed into the main stream—now the south-west reach of the Pyrete. This diverted the head waters of the Glendoon Creek from the Djerriwarrh system, taking from it the reversed drainage which the Glendoon had captured from Jackson's Creek. The history of the Upper Pyrete and its tributaries would thus be:—

(a) They were formed by drainage flowing north to Jackson's Creek consequent on the reversal of the direction of the latter by erosion westward form the Djerriwarrh Fault.

(b) They were captured by the Glendoon Creek, most likely after the volcanic outbursts, the southern grade being much steeper than the northern, partly owing to rejuvenation consequent on an east and west fault through Coimadai.

(c) They were in turn captured from the Glendoon by an eastern tributary of Cataract Gully, to form with this tributary the present Pyrete Creek, the erosive power of the Glendoon having been considerably lessened by the Mount Gisborne lava field.

The following classification of streams may be interesting. In preparing it the authors have had the benefit of Mr. R. A. Keble's co-operation, and have also used his paper on Lava Residuals.[8]

Pre-Newer Basalt Cycle	(a) Pre-Djerriwarrh Fault	Bullengarook (infilled). Eastern and western sub-basaltic streams and tributaries (infilled).
	(b) Post-Djerriwarrk Fault	Upper Jackson's Creek (reversed portion of Bullengarook (infilled). Djerriwarrh. Glendoon. Slocombe's (infilled). Upper Pyrete (originally flowing north). Several infilled streams.
Newer Basalt Cycle		Many streams obliterated by successive lava flows.
Post-Newer Basalt Cycle		Goodman's Creek. Cataract Gully. South-west reach of Pyrete. Jackson's Creek. Riddell's Creek. All streams on Newer Basalt.

VI.—Lower Ordovician.

(a) Distribution and Fossils.

Lower Ordovician rocks were found only to the west of the Djerriwarrh fault. They comprise sandstones, slates and shales and differ little in appearance from rocks of similar age in other parts of Victoria. The prevailing strike seems to be slightly east of north, as compared with a strike of slightly west of north in the Bendigo, Castlemaine and Daylesford districts. The easterly strike, however, prevails in the more southerly Steiglitz area. The predominance of sandstones, the covering of surface soil, the almost entire absence of artificial sections, and a troublesome cleavage, render the delimitation of graptolite zones

8. 7.

difficult. Bendigo, Castlemaine and Darriwil series are all typically represented. The lowest beds seem to be those west of the Djerriwarrh Creek in the south-west of the mapped area. Beds, probably Middle Bendigonian, and lower than any previously recorded from the district, are indicated by—

Tetragraptus fruticosus (4-branched), J. Hall.
Tetragraptus pendens, Elles.
Phyllograptus cf. typus, J. Hall.
Goniograptus thureaui, McCoy.
Goniograptus macer, T. S. Hall.
Didymograptus similis, J. Hall, and others.

Of Bendigonian age also are the rocks of the south-west bend of the Pyrete, though the presence of *Didymograptus bifidus* at at some outcrops indicates the upper beds of the series just below the typical Wattle Gully (Lower Castlemaine) beds of Dr. Hall.[9] The beds are in fact transitional between the Bendigo and Castlemaine series.

Lower Castlemaine beds occur both east and west of these. They were traced for some distance south on the western side of the Djerriwarrh Creek, then they outcrop in the bed of the stream, and finally cross it. These beds are of interest on account of their nearness to Upper Ordovician shales—a point to be enlarged on later—and because in them we found a gasteropod determined by Mr. Chapman to belong to the genus *Helicotoma*, practically the sole representative at present known of the Victorian Lower Ordovician mollusca. The beds yielded—

Didymograptus bifidus, J. Hall.
Didymograptus caduceus, Salter.
Phyllograptus cf. typus, J. Hall.
Tetragraptus pendens, Elles.
Tetragraptus serra, Brong.
Tetragraptus quadribrachiatus, J. Hall.
Clonograptus abnormis, J. Hall.
Goniograptus crinitus, T. S. Hall.
Rhinopterocaris maccoyi, Eth. fil.
Helicotoma sp.

The presence of *D. caduceus* with *D. bifidus* is unusual, but the two species are found together occasionally in the Castlemaine district and elsewhere. On the western side of the Bendigo beds we found in Cataract Gully—

9. 8, pp. 69-70.

Didymograptus bifidus, J. Hall.
Didymograptus caduceus, Salter.
Phyllograptus cf. typus, J. Hall.
Tetragraptus serra, Brong.
Dichograptus octobrachiatus (juv.), J. Hall.
Goniograptus crinitus, T. S. Hall.

From Basin Creek, south of this last locality, Dr. Hall[10] has recorded graptolites belonging to the same zone.

Middle Castlemaine beds with Phyllograptus and D. caduceus occur along the Upper Pyrete.

Upper Castlemaine and Darriwil graptolites are found in many parts of the district, west of Glendoon Creek, on the Glendoon Spur, and at the new but now abandoned slate quarry south-west of Slocombe's Corner, but particularly along Goodman's Creek (Upper Castlemaine), in Cockatoo Gully, and between the Bacchus Marsh Road and Woodend. Along Jackson's Creek, above Gisborne, slate bands are common. At localities like the old slate quarry on the creek north-west of Gisborne, a good collection of Upper Castlemaine forms may be obtained, while further down the creek near Ba 69 and Ba 71, and north of Ba 70, Lower Darriwil forms occur, the following being recorded:—

Didymograptus caduceus, Salter.
„ „ var. *manubriatus,* T. S. Hall var.
„ „ var. *forcipiformis,* Rued. var.
Didymograptus uniformis, Elles and Wood.
Didymograptus v-deflexus, Harris Ms.
Oncograptus upsilon, T. S. Hall.
Trigonograptus, sp.
Diplograptus, sp.
Goniograptus speciosus, T. S. Hall.
Tetragraptus serra, Brong.

From Ba 71 "on the east bank of the Saltwater River one mile north from the Bacchus Marsh Road," Sir F. McCoy's[11] records—

Tetragraptus fruticosus, J. Hall,
Phyllograptus typus, J. Hall,
Dichograptus octobrachiatus, J. Hall,

a perfectly consistent group indicative of the Bendigo series. Repeated search failed to reveal graptolites at the exact spot,

10. 6, p. 202.
11. 1, Dec. 1, pp. 9, 14, 18.

and Mr. F. Chapman kindly examined the Melbourne National Museum collection without finding any fossils from Ba 71. Surface wash may have obscured the outcrop, but field evidence leads us to doubt the occurrence of Bendigo beds at this particular locality. All outcrops we have examined north of the Bacchus Marsh Road have yielded Upper Castlemaine or Darriwil species and these occur plentifully 200 or 300 yards north of Ba 71 along the line of strike. They also occur half a mile to the south.

Outcrops, interesting on account of their field relations, their accessibility, and the representative nature of their facies occur along the railway line south and north of Macedon R.S. The southerly locality, Lower Darriwil, yields almost the same species as Ba 69 and 70, i.e., the typical *Oncograptus* fauna. *Lasiograptus* is also found. A continuation of these beds outcrops in the Turritable Creek a short distance upstream from the crossing of the Upper Macedon Road. The northerly locality—in a cutting north of the 45 mile post—is Middle Darriwil, and, in addition to previously recorded forms, *Cardiograptus morsus*, Harris and Keble, is also common. Localities along the railway further north yielded few graptolites, and those found were in all cases referable to the Darriwil series. Similar graptolites are recorded from Allot. 1, Sect. Va, Newham, by Drs. Skeats and Summers.[12]

North and west of Macedon, and near the Campaspe west of Woodend, there are several outcrops, all of which appear to be of Upper Castlemaine or Darriwil age. At Ba 74, west of Woodend, one of the commonest forms is a narrow *Diplograptus*, found also at Guildford, in the Werribee Gorge, and recorded by one of us[13] as *Diplograptus*, *cf. angustifolius*. Along Goodman's Creek we obtained Upper Castlemaine graptolites from numerous outcrops, some of which may be on the same band of slate. From Cockatoo Gully we have recorded similar fossils, and, in one case, *Oncograptus upsilon*, showing that the beds here approach the Darriwil series. As in the case of the *D. bifidus* beds, our results here are in agreement with Dr. Hall's record.[14]

(b) Structure of Area.

It has been demonstrated that all the Lower Ordovician series except the Lancefieldian are represented in the Gisborne district.

12. 4, p. 41.
13. 18, p. 70.
14. 6, p. 203.

The distribution of the beds shows that the country between Slocombe's Corner and Goodman's Creek forms the arch of a geanticline. This is represented diagrammatically in Fig. 1. The prevailing dip in the east is westerly, apparently owing to inversion, as the Upper Ordovician rocks appear to dip below the Lower Ordovician. The sequence of graptolites denotes a prevailing northerly pitch. This may be partly due to faulting, in which case it would be necessary to assume a down-throw to the north or opposite to that of the larger faults further south. It is both possible and probable that faults, of which we have no knowledge, are responsible for the meagre development of Middle Castlemaine and Victoria Gully beds.

VII.—Upper Ordovician.

(a) Distribution and Fossils.

On the Quartersheets Upper and Lower Ordovician are both included in the Lower Silurian, but Upper graptolites are recorded by Sir F. McCoy from Ba 64[15] (on Jackson's Creek near the mouth of Evans Creek), and from Ba 67[16] (at the junction of Riddell's and Jackson's Creeks). With the recognition of Darriwil graptolites at Macedon the east boundary of the Lower Ordovician was brought within six miles of known Upper Ordovician beds. One of our tasks was to reduce this distance still further. Our plan was to work down Jackson's Creek from Gisborne, but fortune favoured us at the outset, as we discovered Upper Ordovician graptolites in a "wash-out," or gulch, which runs from the Mount Alexander Road to Jackson's Creek, at the south-east of Gisborne township. This discovery pushed the Upper Ordovician boundary about 30 miles west of the longitude of Melbourne.

The Upper Ordovician rocks consist of hard quartzose bands, coarse and fine sandstones and shales. The shales range from black and carbonaceous to a pipeclay-white, and, except in the west of the area, are usually decomposed. All the Upper Ordovician rocks have been subjected to great pressure, to which they seem to have yielded more readily than the Lower Ordovician. The hardest bands are often contorted, and are sometimes pinched out altogether. Slickensided faces are common. The slates in the bed of the Djerriwarrh are traversed by thousands

15. 1, Dec. 1, pp. 10-12.
16. 1, Dec. 11, pp. 33, 34.

of minute faults, rarely with a throw of much more than an inch.

Such is the nature of the Upper Ordovician rocks that it is usually difficult to collect graptolites sufficiently well preserved to enable specific identifications to be made with any confidence. Moreover, so varied are the appearances which a form such as *Diplograptus* can assume with different angles of compression, that even with favourable material diverse views may be taken. Lastly, except for generic purposes, the mere outline of the rhabdosome is of little value when dealing with Upper Ordovician graptolites.

Collections at all extensive have been made from only a few outcrops. Most localities, however, are enormously rich in individuals. Lists of identified graptolites from a few typical localities will give some idea of the fauna. Ba 64, on Jackson's Creek, north of Sunbury, yielded—

Diplograptus, spp. including forms with a dilated virgula.
Climacograptus bicornis, J. Hall.
„ „ var. *peltifer,* Lapworth var.
Dicranograptus ramosus, J. Hall.
„ *zicczac,* Lapworth, or *D. furcatus,* J. Hall.
Dicellograptus cf. sextans, J. Hall.
„ *cf. elegans,* Carruthers.
Glossograptus, sp.
Leptograptus (?).

The identification of the last genus is doubtful. Dr. Hall[17] has recorded a *Leptograptus* from Lancefield, but recognised[18] that it was not a typical member of the genus, and neither his figure nor description of *L. antiquus* seems to present the characteristics of the genus as described by English[19] and American[20] authorities. *Leptograptus* is elsewhere an Upper Ordovician genus and has been recorded by Dr. Hall from the Upper Ordovician shales of the Matlock district.

Ba 67, at the junction of Riddell's and Jackson's Creek, is wonderfully rich in beautifully preserved forms, so that one cannot but regret the absence of the *Dicranograptidae.* We record—

Diplograptus—several species, one of which is very common, and is recorded by McCoy[21] (probably erroneously) as *D. pristis,* Hisinger sp.

17. 9, p. 166, Plate XVII., Figs. 5 and 6.
18. 10, p. 440.
19. 11, p. 104.
20. 12, p. 260.
21. 1, Dec. 1, p. 11, Pl. I., Fig. 6.

Climacograptus, sp.
Glossograptus, recorded by McCoy as *Diplograptus mucronatus.*[22]
Nemagraptus (?).
Cryptograptus tricornis, Carruthers.
Pleurograptus, or an allied genus.
Retiograptoid form.
Didymograptus, sp.—horizontal forms.
Rhinopterocaris maccoyi, Eth. fil.
Siphonotreta micula, McCoy.

A third locality is the Gisborne "wash-out," already mentioned. The shales here are white and light blue, slickensided, and decomposed. In some bands graptolites are plentiful, but, as might be expected, badly preserved; yet, strange to say, forms showing distinct retiograptid structure were found. There occur—

Dicellograptus sextans, J. Hall.
,, *cf. elegans,* Carruthers.
Diplograptus, spp.
Climacograptus, sp.
Glossograptus, sp.
Didymograptus, sp.
Nemagraptus gracilis, J. Hall.
Retiograptus geinitzianus, J. Hall.

Many of the other outcrops are indicated on the map.

No attempt has yet been made to indicate graptolite zones in the Upper Ordovician rocks of Australia, nor has sufficient information been gathered to warrant any detailed attempt. The difficulties encountered in identification have already been mentioned. These difficulties, the poor state of the fossils, and the absence of the economic considerations which directed attention to the Lower graptolite shales of the goldfields, are responsible for the comparative neglect of richly fossiliferous beds within 30 miles of Melbourne. The geological survey of Northern Gippsland[23] has already provided valuable material, and further work in that area may solve problems for which nearer localities furnish insufficient data. We have found that the following distinctions seem to hold good throughout the district we have studied:—

22. Ibid. p. 10, p. 10, Pl. I., Fig. 5.
23. 13, p. 7 (Detailed references in footnote).

(I.) Beds without Dicellograptus and Dicranograptus, but containing Didymograptus, Diplograptus and Climacograptus. The Ba 67 outcrop is typical. Similar beds occur on the Upper Djerriwarrh and elsewhere.

(II.) Beds with the same species as (I.), but with Didymograptus rare, and containing Dicellograptus also. These outcrop at Gisborne, along the Djerriwarrh and Glendoon Creeks, and on the Toolern Creek.

(III.) Beds differing from (II.) by the addition of Dicranograptus, as at Ba 62, Ba 64, Dalrymple's and other outcrops along Jackson's Creek, and also along Evans Creek.

The scattered nature of these outcrops renders correlation difficult, but we are inclined, on phylogenetic grounds, to arrange the beds as under:—

Uppermost—

(I.) Dicranograptus beds.

(II.) Dicellograptus beds.

(III.) Diplograptus-Didymograptus beds.

Upper Ordovician records from other parts of the State,[24] and from New South Wales,[25] seem to show the same three zones, but throw no light on their stratigraphical relations. The absence of Dicranograptidae from Ba 67, the common occurrence of Glossograptus, Didymograptus and Cryptograptus, all forms found also in the Lower Ordovician, and the diplograptid characters of the commonest species of Climacograptus, are some of our reasons for placing this outcrop below the others. On the Toolern Creek a Dicellograptus is found, which is either *D. Smithi,* Rued., or closely allied to it. *Dicellograptus smithi* is cited by Ruedemann[26] as indicating the tendency of a Dicellograptus to develop Dicranograptus characters. If this be so, Dicellograptus beds would be expected below those containing Dicranograptus. In America and Great Britain Diplograptus and Climacograptus survive, as well as precede, the Dicranograptidae. They may therefore occur in beds above the highest given in the above table. From such beds Didymograptus would be absent.

24. 13, p. 7 (Detailed references in footnote).
25. 14.
26. 12, p. 109, et seq.

(b) Relation to Lower Ordovician—Critical Sections.

As far as the writers are aware, there is no record of the observation of the junction of Upper and Lower Ordovician in Victoria. Between Ba 67 and Ba 70, the nearest outcrops of Upper and Lower graptolite shales shown on the Quartersheets, the distance is 7½ miles. Our discovery of Upper Ordovician fossils at Gisborne narrowed the gap to less than two miles. By making traverses further south we still further reduced this distance, and finally succeeded in ascertaining the junction within a few yards. The actual junction cannot be indicated, since, unless one were to judge by lithological characters, there is no evidence by which Upper and Lower Ordovician unfossiliferous rocks may be distinguished. Taken as a whole, Lower Ordovician sandstones are unlike those of Upper Ordovician age, but the test is not one which can be safely applied to any limited outcrop. The shales are more distinctive, but cannot invariably be recognised by texture and colour.

An account will now be given of some sections across the boundary line, commencing near the north of the area, and working south.

(I.) From the extreme north of the district, Messrs. Skeats and Summers[27] record graptolites obtained near "Cheniston," Upper Macedon. Dr. Hall referred these to the Darriwil series. In the same beds we discovered *Loganograptus logani,* confirming the reference to Lower Ordovician. To the east of the Barringo Creek badly preserved graptolites were found in metamorphosed shales. Whether they were Upper or [27A] Lower Ordovician could not be determined. North of Riddell's Creek, further east, *Diplograptus* and *Climacograptus* were obtained.

(II.) North of Gisborne township, a short distance upstream from Cherry's saw mills, Lower Ordovician graptolites occur. Arenaceous shales in the bed of an old channel of Jackson's Creek yielded—

Didymograptus caduceus, Salter.
Didymograptus, spp.
Tetragraptus quadribrachiatus, J. Hall.
Diplograptus, sp.
Glossograptus, sp.
Loganograptus, cf. logani.

27. 4, p. 41.

27A. The discovery of *Climacograptus bicornis,* var. *peltifer,* Lapw. var., has since shown these beds to be Upper Ordovician.

Trigonograptus ensiformis, J. Hall.
Cryptograptus tricornis, Carruthers.
Phyllograptus, sp.
cf. Thamnograptus.
cf. Cardiograptus.

This assemblage of graptolites presents several interesting features. The association of *Diplograptus* with *Phyllograptus* is found elsewhere, as for example at Ba 29, Sect. 20, Newham, from which locality came some of the first Australian graptolites to be described.[28] The Newham or Cobaw outcrop is remarkable, an isolated patch of slate with well preserved graptolites in a soil covered and unfossiliferous area. Dr. Hall[29] recorded from it—

Didymograptus caduceus, Salter.
Diplograptus palmeus, Barrande.
Glossograptus mucronatus, J. Hall.
Tetragraptus quadribrachiatus, J. Hall.
Phyllograptus typus, J. Hall.
Goniograptus, sp.
Lasiograptus, sp.,

and believing from his Castlemaine observations, that *Phyllograptus* disappeared below the Upper Castlemaine horizon,[30] concluded that both the Darriwil and Castlemaine series were represented. His belief that *Phyllograptus* was not found with *Loganograptus* was also probably responsible for the identification of Goniograptus instead of *Loganograptus.*[30] There is no doubt whatever that the collection is quite homogeneous. *Phyllograptus, Diplograptus* and *Lasiograptus* may be obtained on the same slab, and all the fossils are from one isolated band. One of us[31] has shown in an earlier paper that *Phyllograptus* reappears in the Middle Darriwil, and it now seems probable that it may persist at some localities into the Upper Darriwil series. The finding of *Cryptograptus tricornis* and the common occurrence of *Diplograptus* at the Gisborne outcrop, would place it very high in the Lower Ordovician, and it may be the highest bed yet recognised. *Cryptograptus tricornis* is elsewhere in Victoria an Upper Ordovician form, but it occurs in Lower Ordovician shales near Woodend, and at the "Cheniston" locality.

28. 1 and 15.
29. 16, p. 126.
30. 7, p. 73 and 10, pp. 441, 443.
31. 18, p. 67.

On the opposite side of the Mount Alexander Road, about 400 yards downstream to the east, a submerged band of rotten blue slate yielded *Diplograptus* only, but exhaustive search was impossible. The nearest Upper graptolite beds are about half a mile eastward, though unfossiliferous shales closer at hand are probably Upper Ordovician.

(III.) In Sect. 14, east of Gisborne Cemetery, decomposed blue shales gave *Diplograptus*. The age of the beds is unknown.

(IV.) In the bed of the Djerriwarrh Creek, between Allots. 4 and 5, Upper Ordovician graptolites occur. After crossing a basalt residual—the Glendoon Spur—Upper Castlemaine graptolites are found. The distance between the two outcrops is about 500 yards, and basalt covers the junction.

(V.) Upper Ordovician graptolites are found on the southern slope of the Glendoon Spur, and in the bed of the Glendoon Creek at its foot *Diplograptus, Climacograptus, Cryptograptus* and *Dicellograptus* occur, while the ridge on the western side of the creek gave—

Didymograptus caduceus, Salter.
„ „ var. *manubriatus,* T. S. Hall, var.
Didymograptus, horizontal species.
Trigonograptus, sp.
Goniograptus speciosus, T. S. Hall.

A traverse here must cross the junction of Upper and Lower Ordovician. We made several trips up and down the Glendoon Creek, but are unable to find any structural break. The blue Upper Ordovician slates are succeeded upstream by green and brown arenaceous rocks. The softer and probably fossiliferous bands are poorly exposed. The first fossiliferous band above the *Dicellograptus* beds yielded only *Diplograptus* and *Cryptograptus tricornis,* Carruthers, and may be either Upper or Lower Ordovician, though we are inclined to regard it as Upper. In unpromising material further upstream we found the continuation of the hillside beds, and obtained the same forms as from the hill, with the exception of *Goniograptus speciosus,* and in addition—

Didymograptus v-deflexus, Harris Ms.
Oncograptus upsilon, T. S. Hall,

indicating plainly the Lower Darriwil horizon. There are variations of strike, but no clear line of division is indicated. As has been stated, the *Cryptograptus* shales between these Darriwil beds and the *Dicellograptus* slates down stream, may be Upper

or Lower Ordovician, but in either case, the vertical distance between the Upper and Lower fossiliferous rocks can only be about 100 feet.

The *Dicellograptus* shales outcrop downstream in the Glendoon Creek for some distance, and are continued south in the bed of the Djerriwarrh. A cliff on the right bank of the Djerriwarrh yielded—

Diplograptus.
Climacograptus.
Glossograptus.
Dicellograptus, cf. *sextans,* J. Hall.
Cryptograptus tricornis, Carruthers.
Nemagraptus gracilis, J. Hall.
Retiograptus, cf. geinitzianus, J. Hall.

The next fossiliferous beds downstream yielded only a few specimens of *Didymograptus caduceus* after a long search, but the vertical distance between these Lower Ordovician beds and the Upper Ordovician cannot be greater than the interval between two zones of the Lower Ordovician at a typical locality in a district like Castlemaine. A little further south, Lower Castlemaine beds are found. The graptolites, etc., from these have already been listed on page 47. We measured the distance from these beds up a small tributary to *Dicellograptus* beds, and found it to be about 100 yards. The same beds were also traced north along the western bank of the creek, to a point not far west of Upper Ordovician outcrops in the creek itself. This was as far south as our detailed observations extended; but, further south, Middle Bendigo graptolites were obtained from the bed of a western tributary of the Djerriwarrh, and *Tetragraptus fruticosus* and *Didymograptus bifidus* were obtained from the Boggy Creek, west of Toolern Vale.

(c) Summary.

Nowhere was the actual junction between Upper and Lower Ordovician detected. The two series are undoubtedly unconformable, though the unconformity is not apparent in the field. It is difficult to imagine that Lower Castlemaine beds in one place, and Lower Darriwil, a little further north, are only a few hundred feet, or less, below *Dicellograptus* shales, unless they have been brought into that position by faulting, for there is nothing to indicate any great difference in the conditions of sedimentation at Gisborne, compared with those prevailing at

Bendigo, Steiglitz, or Castlemaine, and there cannot be the complete succession of beds between the *D. bifidus* beds and the Djerriwarrh *Dicellograptus* beds. The uniformity of the junction—a line running nearly north and south for several miles—suggests that we are most likely dealing with a fault. The Djerriwarrh valley appears to follow the fault line for some distance. All that can be said as to the age of the fault is, that it seems to be much older than the tertiary faults of the Werribee District. It is certainly pre-Newer Volcanic, and so old that, though it must have meant a considerable vertical displacement, the contour of the area is not dominated by it, though its effect on the physiography has been important. The throw is probably small in the north, and increases southwards. The down-throw or eastern block seems to have pivoted on the Macedon platform, and the break in the continuity of the shales north of Gisborne is probably small.

VIII.—Riddell Grits.

(a) General Survey.

Two miles south-east of Gisborne, a small stream known locally as Watson's Creek, crosses the Mount Alexander Road. On QS. 7 NW. there is the following note on this locality: "Hard gritty sandstone, grey and pinkish-white, containing minute fragments of fossils, is used for road metal." On some copies of QS. 7 NE. the word "Fossils" appears in white letters on the coloured background south of Mount Holden, but it is absent from others, probably of another edition. The absence of fossiliferous Ordovician sandstones of Ordovician age in Victoria, as far as we were aware, led us to examine the Watson's Creek outcrop carefully. The resemblance the rock bore to that which occurs at Allot. 11, Kerrie, referred to the Upper Silurian by Mr. Chapman,[32] was at once apparent, but the chief fossils were only casts of crinoid stems and obscure fragments of brachiopods. Our partial success led us to examine carefully

32. 17, p. 225.

Note.—While this Paper was in course of preparation, fossils were discovered in Lower Ordovician grits or coarse sandstones at Castlemaine by Mr. A. L. Hopkins, at that time a student at the Castlemaine High School. The commonest fossil has been identified by Mr. Chapman as an *Orthis* comparable with *Orthis flabellulum*, Sow. or *O. pectinella*, J. Hall. Trilobite remains, probably referable to *Agnostus*, also occur, while impressions of phyllocarids are common. The writers have discovered indeterminate brachiopod remains near the Campaspe River, west of Woodend, and it is probable that Ba 75, QS. 10 NE. refers to a similar occurrence. All these outcrops are in the Castlemaine series.

every outcrop of sandstone and grit discovered. It was found that rocks outcropping at numerous places in the district could conveniently be grouped together, and for convenience we have called the series the Riddell Grits. The undoubted Upper Ordovician rocks have already been described—homogeneous sandstones and carbonaceous shales, usually finely laminated, and in extreme cases weathering to a soft clay. The most prominent beds of the Riddell Grits are of coarse sandstone and grit; in some places, as in Jackson's Creek, above "Dalrymples'," a gravel conglomerate. The bands are persistent, but within any band the texture changes, passing from grit to a fine sandstone or quartzite, evidently the effect of currents during deposition. The grit bands are slickensided, and their outer layers often show bulges and channels where they have been forced into less resistant rocks. In the coarser grits there are smooth-lined cavities resembling casts of fossils, but most likely caused by the removal by solution of small clayey patches. The grits are fossiliferous, but such is the nature of the rock, that well preserved fossils are unobtainable. Brachiopod casts, occasional gasteropods, corals, polyzoa, and most commonly the impressions of crinoid stems, are to be found. Mr. Chapman very kindly examined a large quantity of unsatisfactory material for us, and his identifications are given on pages 69-71.

With the grits, and in some localities, interstratified with characteristic grit bands, are mudstones or shales, brown, rubbly, and less finely laminated than the typical graptolite shales. There are also thin-bedded fine micaceous sandstones or arenaceous shales. It will be seen that the Riddell Grits represent a more shallow water deposit than the Upper Ordovician rocks already dealt with. Determination of their age is fraught with difficulty. The following points have to be considered:—

(i.) It is impossible to draw a sharp distinction between shales associated with the Grits, and normal Upper Ordovician shales, and the relation of the Riddell Grits to the Upper Ordovician may depend on the relation of the shales of the two series. As in the case of Lower and Upper Ordovician, typical shales of the two series differ greatly from each other, but no safe test can be applied to a limited outcrop. On account of this difficulty, and because of the nature of the country, it is difficult to ascertain the field relations of the Grits.

(ii.) *Diplograptus-Climacograptus* shales are interstratified with the Grits (though naturally graptolites are hard to find), and remains of *Diplograptus* occur in the Grit itself at some localities. At one outcrop—on the Western Kororoit Creek—sandstones apparently of the Grit series, yielded from thin, included, impersistent shales *Dicellograptus,* as well as *Diplograptus.* The sandstones in this case were not quite typical Riddell Grit, but we believe them to belong to that series.

(iii.) The fauna of the Grits, other than graptolites, in Mr. Chapman's opinion is Silurian, and even Yeringian (Upper Silurian). Mr. Chapman states: "The fossils indicate a mid or newer Silurian horizon. As a distinct horizon of grits, I should say they were basal, and, from the fossils, basal Yeringian. The *Leptaena* is of a type only found in the Newer Silurian, as also the *Encrinurus* and cf. *Eridotrypa.* The faunal elements suggesting an older phase of the Silurian, are the abundance of *Camarotoechia* and *Rhynchotrema.*"

(iv.) Though there is no evidence of the fact, the Grits may not be all of the same series. Mr. Chapman states that as far as the fossils go, there is no evidence of more than one horizon, and there is a remarkable similarity in the appearance of the Grits at all outcrops. Still, at Springfield, east of Romsey, a lithologically similar band is interstratified with *Monograptus* shales.

Having stated some of the difficulties of the question we shall now proceed to discuss it.

(b) Field Relations—Critical Localities.

(1) Mouth of Watson's Creek—"Dalrymple's."

Following Watson's Creek to the north-east from the Mount Alexander Road, a walk of less than two miles brings one to its junction with Jackson's Creek, which here swings in from the west through a narrow gorge in the basalt, meanders through a small alluvial flat, and then continues eastward, hugging the foot of a high northern bank. This is an interesting locality, though, like many critical sections, its interpretation is difficult. (See Fig. 2.)

The first sedimentary rocks exposed upstream are Grits, striking N.40°W., and dipping to the east. Then comes a series of muddy grey shales, soft and decomposed, and as far as we can ascertain, unfossiliferous. These are succeeded by a bluff of west-dipping sandstone with thin shale bands. The strike of these rocks is almost due north. Below the bluff, the section is not as clear as one could wish, but a coarse Grit band seems to run up into the hill to the north. Associated with it are rubbly brown shales or mudstones, such as are charactertistic of the Grit series elsewhere, and grey mudstones with pellets of gravel, seemingly derived from the coarse band. In the brown shales we find Diplograptus, and from the mudstone we obtained a single small gasteropod. The bed of the creek is littered with large angular fragments of grit. All these beds dip to the west, and there is a syncline between them and the first Grit mentioned above. They strike more to the west than the sandstones of the bluff. The grit in the bands here is usually coarse. It might be regarded as a light conglomerate, and joints or shearing planes have cut pebbles and matrix in a manner suggestive of the Kerrie Conglomerate on a small scale. Among the debris of landslides from the steep bank of the creek are blocks of Upper Ordovician shale, which yielded a small collection of fairly well preserved graptolites. The band from which they are derived is to be found some height up the bank, but its relation to the shales below is obscured by soil and debris. We obtained—

Diplograptus, sp.
Climacograptus, sp.
Dicellograptus elegans, Carruthers.
Dicellograptus complanatus, Lapworth.
Dicranograptus furcatus, Hall, or *D. ziczac,* Lapw.

The rubbly shales cross the creek to the south, where the Grit bands stand out prominently in the bed of the stream.

On the downstream side of the alluvial flat we come to contorted rubbly shales striking at first N.10°W., separated by an unconformity from normal carbonaceous *Dicellograptus* shales dipping west, and striking N.40°W. A grit band crosses the stream further east, striking nearly north, but a soil covered flat separates it from the graptolite shales. To the north, a small tributary gully seems to expose only grits and *Diplograptus* shales, the *Dicellograptus* shales passing under the hill. The strike of the grits as one descends this gully from west to east,

varies from north-east to north, and the *Diplograptus* shales below them strike N. 20°W. The dip throughout this section is westerly, and the hill between the gully and the main creek shows nothing but grit, which seems to pass right over the *Dicellograptus* shales outcropping in the bed of Jackson's Creek.

This represents the most complete section, though it is incomplete at critical points. South of the main creek a steep " wash out " descends to Watson's Creek. The uppermost beds, below basalt, are arenaceous shales, apparently bent in a syncline. Below are grit, sandstones, and rubbly shales or mudstones, all apparently conformable, striking N. 10°W., and dipping west. Below the lowest grit band *Diplograptus* and (?) *Dicranograptus furcatus* were obtained, but are very rare. In Watson's Creek, to the southward, are rubbly *Diplograptus* shales, striking N. 10°E., and dipping west, succeeded after an interval, by a grit band which strikes N. 10°W., and, if continued north, would pass through the " washout." Two or three hundred yards to the south-west, just past a north and south fence, *Dicellograptus* shales outcrop, striking N. 10°E., and dipping west, while still further upstream, decomposed shales, apparently of the Grit series, dip East, and strike N. 20°W. Grit boulders litter the hill slopes to the south-west. The *Dicellograptus* shales last mentioned are almost certainly identical with those on the bank of Jackson's Creek to the north, the graptolites of which are given in the list on pages 64, 65. Not only are the graptolites identical, but the colour, texture and lamination of both beds are identical and distinctive, not resembling those of any other locality with which we are acquainted. This is of importance in attempting a correlation of the rocks of the area.

We have dealt with this area in fair detail, because it represents perhaps the most intimate association of Grits and normal Upper Ordovician.

Our interpretation of the features we have described is only provisional. We sum up our observations as follows:—

1. Grits and rubbly *Diplograptus* shales are of the same series and are interstratified.

2. The " wash out " section indicates—

   (a) A syncline in the Grits.

   (b) *Dicranograptus* in associated shales.

We at first thought that there was evidence of an unconformity between the Grits and these shales, but further investigation leads

us to alter our opinion. The gap between Grits and *Dicranograptus* shales seems to be due solely to superficial debris.

3. This syncline is also indicated in Jackson's Creek, and by the occurrence of similar *Dicranograptus-Dicellograptus* shales on either side of the Grits.

4. Grits occur further east, but their relation to those already mentioned is not shown. They also cover the hill in the north of Jackson's Creek.

Our conclusions are:—

1. The Grit series here is in all probability Upper Ordovician.
2. It overlies *Dicranograptus* shales.
3. There is no evidence of normal Upper Ordovician graptolite shales overlying the Grits.

(ii.) Lancefield Junction.

The Grits outcrop on the western slopes of Jackson's Creek, south of Lancefield Junction, and compose the hills as far south as Evans Creek, but were not found immediately south of that stream. These hills are exceptionally barren, comparing unfavourably even with Lower Ordovician and Kerrie Conglomerate. This locality will be dealt with in two parts—(a) the section exposed in the creek, and (b) the hills south of the creek.

(a) Jackson's Creek, south of Lancefield Junction.—As Jackson's Creek comes from the west immediately before turning south at Lancefield Junction, Grit ridges appear on the right bank, and, if continued north, should cross the stream. Directly in the line of strike of these ridges, a low cliff forms the south bank of the creek, and, viewed from the far side of the stream, seems to be normal Upper Ordovician shales with a sandstone bar about the middle of the section, and it is so shown on QS. 6SE. The bank is almost vertical, and there is a deep pool at its foot. A false step may mean an undesired bath. Working from the west along this section we cross *Diplograptus-Climacograptus* shales dipping east and broken by faults. The sandstone band is typical Grit. Some feet wide at the top of the bank it rapidly narrows, and is less than a foot wide at water level, and probably does not extend much further. It is followed by vertical or west-dipping shales, which gradually turn over to the east. These shales yielded *Diplograptus, Climacograptus* and *Glossograptus,* and the main Grits overlie them. On top of brown shales comes

an eight or nine inch band of grit, then two feet of shale, and finally massive grits.

The section is inconclusive on account of the absence of typical beds immediately to the east. The shales of this cliff are certainly Upper Ordovician. It is our opinion that all the rocks exposed belong to the Riddell Grits. If this be so, the Riddell Grits would appear to be Upper Ordovician also, nor would the position be altered if it should later be proved possible to separate the shales from the Grit series. As to what lies above the Grits we have here no evidence.

Further up the creek, *Dicranograptus* shales form a steep bluff, and after another break, we again find Grits interbedded with rubbly shales, with an occasional *Diplograptus*. Sandstones along this part of the creek also seem to belong to the Grits.

As this is perhaps the most accessible, and one of the most critical localities for the relations of Grits and Upper Ordovician shales the following references to QS. 6 SE. are given:—

The "arenaceous and micaceous light coloured shales and thin-bedded sandstones, 65-70°W, 25°S.," near the mouth of a small eastern tributary are *Dicranograptus* shales.

The bed rock across which this note is printed on the Quarter Sheet is Riddell Grit.

The "shales 80°W., 10°S." are Upper Ordovician, as are also the "cream-coloured and bluish-grey thin laminated shales and sandstones," further north.

The "bluish-grey and light coloured shales, middle bed sandstone, 75°E., 15°N.," are those just described in detail. The middle bed is Grit, and the eastern Grit band should be shown above the first letters of "sandstone."

The "bluish-grey shales 50°E., 5°N." are *Dicranograptus* shales.

The "coarse, quartzose grit, E. 30°N. and E. 40°N.," are the Grits referred to as interbedded with rubbly *Diplograptus* shales.

Grits occur also near the western limit of the bed rock area shown. The section is not continuous, as would be inferred from the Quarter Sheet, for between the various outcrops the bed rock is obscured by basalt or the wash from it.

The "white sandstone E. 65°S." is interstratified with carbonaceous shales, which yielded—

Diplograptus, sp.
Climacograptus bicornis, J. Hall.

Dicranograptus nicholsoni, Hopkinson.
Dicranograptus furcatus, Hall, or *zic-zac,* Lapw.

The "purple grey shales" at the mouth of Riddell's Creek are at the locality Ba 67, and are Upper Ordovician.

(b) Lancefield Junction, south and west of Jackson's Creek.—We have already mentioned the Grit hills which lie between Lancefield Junction and Evans Creek. Two ridges, composed of Grit, run almost north and south, converging towards the south. Each ridge represents a massive band, or series of bands, of grit, with fragments of which their summits and slopes are littered. The strike of the more westerly bands is about N. 20°W., and the dip east, so that the convergence of the two ridges is probably due to an actual convergence of two bands of grit, or of the same band on opposite limbs of a syncline pitching north from Evans Creek. If this view be correct, the western limb would be represented by the faulted band in Jackson's Creek, while the eastern limb would be indicated by the low outcrop exposed east of this, the limbs being represented by the 75°E. 15°N., and the 75-85°W., 12-15°S., of QS. 6 SE. Such a pitching syncline would also explain our failure to find Grits between Sunbury and Evans Creek. In the small creeks which drain these Grit ridges bed rock is rarely exposed, with the exception of the more prominent grit bands, but in a few places the streams have worn down on to brown rubbly mudstones or shales. One such outcrop directly between the two ridges, and on our supposition above them, yielded *Diplograptus*.

Near the head of Evans Creek Grits outcrop also. The strike is N. 6°E. They are not seen in contact with the *Dicellograptus-Nemagraptus* shales downstream, which appear unconformable with them and below them. A north and south continuation of these last bands would take one to the "quartzose grits" on Jackson's Creek (QS. 6 SE.), and to the Grits of Mount Tophet and The Gap.

The area between the Jackson's Creek section described in (a), and Evans Creek, represents the largest continuous exposure of Riddell Grits in the district. A study of QSs. 6 SE. and 7 NE., or of the military map of Sunbury, will show the two ridges running south towards Evans Creek, separated by a north and south valley. Following the creek south from Lancefield Junction, all the rocks exposed in its bed as far as due west of the 28 mile post on the railway are *Dicranograptus* shales

striking slightly west of north, and dipping west. Then in the river, sandstones and brown rubbly mudstones are exposed, unfossiliferous, but seemingly of the Grit series. Further south, at the bend from south to east, north of Ba 64, a heavy fossiliferous Grit band crosses the creek, dipping west, and forming a small waterfall. Below it are conformable rubbly mudstones and shales, and then, after a space, we come to the *Dicranograptus* shales of Ba 64 striking almost due north, and dipping steeply to the east.

Ascending the valley of Evans Creek, the first rock exposed is an isolated exposure of grit, apparently the projecting top of an almost completely buried grit band. About 500 yards up from the river an easterly grit band crosses Evans Creek. Upstream from this there are numerous sandstone and shale bands, but no fossils were obtained from any of the sandstones, although there seemed to be no unconformity between them and the Grits to the east. A little over a mile upstream, the characteristic *Dicranograptus* shales appear. The shales in the interval are so interstratified with hard sandstones, that no detailed examination of them could be made. *Diplograptus* and *Glossograptus* were obtained from one band.

This area again gives no information about beds overlying the Grits. In the apparent syncline between the two Grit ridges the shales which there seem to overlie the Grit bands are most likely portion of the same series.

(iii.) Conglomerate Creek.

At the junction of Conglomerate Creek with Riddell's Creek Grits and *Diplograptus* shales are seen to underlie the Conglomerate. The Grits here lie above and to the east of the shales which yielded *Diplograptus*. In spite of the differences of strike and dip, it is possible that the shales here may belong to the Grit series. The shales dip east, and strike N. 10°W., while the Grits dip west, and strike N. 10°E. A band of Grit with the same strike runs up the slope towards the house on the spur, while further east are arenaceous shales. (See Fig. 3.)

(iv.) Bracken Gully.

In a small gully west of Conglomerate Creek Grits appear to pass under the Kerrie Conglomerate. The Grits outcrop in the floor of the gully. As the stream is followed northwards, a

small waterfall is reached. The lower four or five feet are Grit. Above lie impersistent layers of shale, and then the main mass of the Conglomerate. The Grit at the junction is penetrated by quartz veins, one of which in the base of the Conglomerate shows slickensides, the direction of movement being almost vertical. The shales on the hillside to the west yielded numerous specimens of poorly preserved *Diplograpti,* and similar fossils are found lower down the gully. The strike of the Grits and their relation to the shales at this locality could not be determined. Still further west, Grits appear at the creek level, while, higher on the slopes is the Conglomerate. A gully to the west shows thick bedded shales or mudstones forming, as it were, a pavement in the creek.

(v.) Sandy Creek Road.

On the Sandy Creek Road, near Allot. 76, a small cutting shows quartzose Grits, overlying *Dicellograptus* shales not quite conformably.

(vi.) Western Kororoit Creek.

South of the Grit outcrop at Watson's Creek on the Mount Alexander Road are other Grit outcrops—on the Eastern Kororoit Creek, north-west of Mount Aitken, north of the Western Kororoit Creek (Allots. XXVI.-XXVIII.) and along the same creek near where the parishes of Buttlejork, Yangardook and Holden meet.

Near the mouth of the small stream from Allot. XIX., Gisborne, are bluish *Dicranograptus* shales striking between E. and N.E., a most abnormal strike for this district, and dipping 65°N. North and south of these shales, not seen in contact with them, but apparently deflected by them, are sandstones with thin shale bands. The strike some 100 yards down stream is N. 20°W., but it changes further north to N. 18°E. The dip is steeply to the east. The sandstones contain brachiopods and the shales, *Diplograptus* and *Dicellograptus,* though graptolites are rare, and the shales are not such as would be expected to contain graptolites at all. Thick bedded sandstones outcrop further upstream, and along the Buttlejork tributary a vertical Grit band, striking N. 15°W., is succeeded by normal blue-black *Dicellograptus* shales which, at first vertical, turn and dip east at a high angle. Unless the beds are inverted we have here the only case where Grits appear to underlie *Dicellograptus* shales. This Grit band

is responsible for the south bank of the stream being littered with angular fragments, which yielded crinoid remains, brachiopod fragments, polyzoa, and, strange to say, *Diplograptus*.

(vii.) Other Localities.

On the Romsey Road (Sect. 11, Kerrie) the Grits and associated shales are alone visible. (See Fig. 3.)

At the head of Evans Creek, Grits outcrop, and have already been mentioned. Their relation to *Nemagraptus—Dicellograptus* shales lower down the creek is not clear. If massive sandstones just upstream from the shales belong to the Grit series the two are in all probability unconformable.

Other areas of Grit occur near Mount Holden, south and west of Red Rock, and at The Gap and Mount Tophet. Southwest of Mount Tophet we get *Diplograptus-Climacograptus* shales, but their relation to the Grit is not evident. They may be its associated shales.

The close relation of the Grits to the normal Upper Ordovician will be at once seen from the following summary:—

I. "Dalrymple's"		
	(a) "Wash-out"	Grits apparently bent in syncline overlying *Dicranograptus* shales. Dip and strike in agreement, and beds apparently conformable.
	(b) Jackson's Creek	Grits apparently overlying *Dicranograptus* shales. Faulting. Junction not seen.
	(c) South of "Wash-out"	*Diplograptus* shales in creek, then Grit band and, after a considerable space, *Dicranograptus* shales. Relations not shown.
II. Lancefield Junction		
	(a) Jackson's Creek	Grits apparently overlying conformably *Diplograptus* shales and faulted with them.
	(b) South of (a)	Grits apparently forming syncline, overlying *Dicranograptus* shales. Junction not observed. On west passing to normal Upper Ordovocian without any observed unconformity.
III. Conglomerate Ck. and Bracken Gully		Grits and *Diplograptus* shales apparently folded together. Some difference in strike.

IV. Sandy Creek Road -	Grits overlying with some unconformity *Dicellograptus* shales.
V. Western Kororoit Ck. -	
(a) Eastern tributary	Vertical Grits apparently conformable with *Dicellograptus* shales and seeming to underlie them. The high angle of dip makes deductions unreliable.
(b) Main stream	Thick-bedded fossiliferous sandstones and *Dicellograptus* shales unconformable with *Dicranograptus* shales.

The Riddell Grits—coarse and fine sandstones, with associated *Diplograptus* shales, usually rubbly—seem everywhere to be closely associated with Upper Ordovician shales. On the field evidence, and on the evidence of their graptolites, they might well represent a shallow water phase of the Upper Ordovician.

There is no doubt that the Grits overlie *Dicranograptus* shales, apparently conformably. With the exception of the outcrop along the Western Kororoit Creek, there is no evidence of beds overlying the Grits conformably. Since along the Djerriwarrh Creek Upper Ordovician shales seem to pass below Lower Ordovician rocks, the result of faulting or overfolding, it is unsafe to generalise and state that the Grits are interstratified with the normal Upper Ordovician shales. The absence of overlying beds throughout most of the area lends considerable weight to the theory that they represent the last phase of the Upper Ordovician, and mark the beginning of the change to the shallower water conditions which prevailed during the Silurian period. At any rate, the presence of *Dicranograptus* below the Grits would seem to place them well up in the Upper Ordovician.

(c) Fossils other than Graptolites.

Fossils are abundant in the Grits, but are poorly preserved as casts. Mr. F. Chapman, A.L.S., of the National Museum, Melbourne, has identified the followings forms:—

(I.) "Dalrymple's," North-west of Red Rock, Gisborne.

(?) *Plasmopora.*
cf. *Stylaraea.*
(?) *Fenestella.*
cf. *Eridotrypa.*
Leptaena, sp.
Orthis, sp.

cf. *Rhynchotreta.*
Camarotocchia, sp.
Spirifer, sp.
cf. *Loxonema.*
cf. *Pleurotomaria.*
Heliolites sp. near *H. megastoma,* McCoy.
(?) *Heliolites* or allied form.
(?) *Rhynchonellid.*
(?) *Cannapora.*
(?) *Conchidium.*
(?) Monticuliporoid.

The species of *Heliolites* is distinct from the usual form found in the Yeringian in having the siphonopores feebly developed and the autopores crowded.

(II.) South of Red Rock, Gisborne—
cf. *Eridotrypa.*
Pseudocrinites sp. (food-groves, casts), seven specimens.

(III.) South-west of Lancefield Junction—
Coral (probably belonging to the *Chaetetidae).*
Rhynchonellids, indet.
Orthis (?) sp. (of the *Platystrophia* type).

(IV.) North-west of Mt. Aitken, Gisborne—
Polyzoa, indet.
Leptaena sp.
Camarotoechia sp.

(V.) Watson's Creek, Mt. Alexander Road, Gisborne—
cf. *Monotrypa.*
(?) *Rhynchotrema.*
Rhynchotreta sp.
Camarotoechia sp.

(VI.) Allot. 11, Kerrie, Romsey Road, Riddell—
Polyzoa, indet.
Leptaena sp.
Orthis sp.
Camarotoechia sp.
Rhynchotremea sp.
Atrypa sp.
Encrinurus sp.
cf. *Rhynchotreta.*
Cyrtolitid gasteropod (cast).

(VII.) Upper Western Kororoit Creek—
Polyzoa, branching form.
Crinoid, columnar, and impressions and moulds of crinoid arms.

Mr. Chapman adds: "The Fossils indicate a mid or newer Silurian horizon. As a distinct horizon of grits, I should say they were basal, and, from the fossils, basal Yeringian. The *Leptaena* is of a type only found in the Newer Silurian, as also the *Encrinurus,* and cf. *Eridotrypa*. The faunal elements suggesting an older phase of the Silurian are the abundance of *Camaratoechia* and *Rhynchotrema*." These identifications were made at an early period of our investigation, and represent the more obvious features of the fauna. Since they involved a distinct break between Grits and Upper Ordovician, and the field evidence pointed to a close connection, a more thorough search was instituted, resulting in the discovery of *Diplograptus* remains in the Grits themselves, and of *Diplograptus* and *Climacograptus* in shales interstratified with them. These fossils are rare, many hours of search resulting in the discovery of less than half-a-dozen specimens, but that they are typical is shown by their widespread distribution. They were found at "Dalrymple's," Lancefield Junction, Watson's Creek, and the Western Kororoit. This led us to transfer to the Grit series *Diplograptus* shales which we formerly considered distinctly Upper Ordovician, but which are of coarser texture, and more rubbly than the normal graptolite shales, and which are closely connected with grit bands. Since such shales had yielded *Dicranograptus* at "Dalrymple's," it was of importance to determine their relation to the Grits. This junction is obscured by soil, but after careful search, we are of opinion that shales and grits are here conformable.

We have also Messrs. Skeats and Summers' accounts of resorted Kerrie Conglomerate pebbles in Lower Silurian mudstones at Springfield. These mudstones are portion of a series which contains grits like the Riddell Grits in texture and fragmentary fossils, but which is Silurian, *Monograptus* occurring in shales above and below it.

We assume, as will be shown later, that the Riddell Grit is older than the Kerrie Conglomerate, and, if we adopt Messrs. Skeats and Summers' theory of the origin of the Springfield pebbles, then the Riddell Grit would be not later than the Lower Silurian.

(d) Summary.

For the sake of clearness we shall recapitulate our results:—

(1) The Riddell Grits are a series of sandstones, grits, mudstones, and shales, the shales being typically more rubbly than the common Ordovician graptolite shales, and differing in colour and texture.

(2) The associated and interstratified shales contain *Diplograptus* and *Climacograptus,* and shales, seemingly of the same series, yield *Dicranograptus* at one outcrop, and *Dicellograptus* at another.

(3) The brachiopods, corals and crinoids obtained from the Grits present a mid or newer Silurian facies, with an admixture of older forms.

(4) The Grits seem to overlie normal *Dicellograptus-Dicranograptus* shales, but have not been seen interstratified with such shales.

(5) The Grits underlie the Kerrie Conglomerate north-west of Riddell.

Our conclusions are as follow:—

(i.) The Grits, with their associated shales, etc., represent a shallower water series than the normal Upper Ordovician graptolite shales.

(ii.) They are probably of Upper Ordovician age, and since they overlie *Dicranograptus* beds, are probably late Upper Ordovician.

(iii.) From (a) their resemblance in texture, etc., to that of Silurian rocks as at Springfield, and (b) the absence of unmistakably overlying Upper Ordovician rocks we think it probable that the Riddell Grits were formed towards the close of the Upper Ordovician, probably during differential movements, which closed the Ordovician, and ushered in the Silurian. In placing the Grits as Upper Ordovician, we emphasise their graptolite fauna more than the brachiopods and other forms. *Diplograptus* and *Climacograptus* range into the Lower Silurian, but *Glossograptus, Dicranograptus* and *Dicellograptus* do not. Still, the only graptolites found in undoubted Grits have been *Diplograptus* and *Climacograptus.*

IX.—Kerrie Conglomerate.

(a) Field Relations.

Messrs. Skeats and Summers[33] have drawn attention to the difficulty of understanding the relation of the Kerrie Conglomerate to neighbouring rocks. For descriptions of the Conglomerate reference should be made to their memoir or to Mr. Hart's paper. Messrs. Skeats and Summers[34] state that "it is probable that a line marking the western extension of the Conglomerate would indicate the junction between Upper and Lower Ordovician rocks in this area," and in another place mention[35] that the Conglomerate "overlies apparently unconformably shales from which no fossils were obtained." They state that the Conglomerate is in their opinion basal Upper Ordovician. In the absence of fossils any opinion was necessarily tentative. The shales are brown and light blue, and very rubbly. There are occasional narrow dark blue bands. In these respects they are unlike the Lower Ordovician shales with which we are acquainted, but closely resemble Upper Ordovician shales on Jackson's Creek. We had found that at the latter outcrops, graptolites occurred in the dark bands, and carefully splitting a dark band at Conglomerate Creek, we obtained several specimens of a *Diplograptus* resembling those found at other Upper Ordovician outcrops. At two localities further west similar graptolites were obtained. These shales cannot be referred to beds below the Upper Ordovician. The shales apparently underlie the Conglomerate, which outcrops further up the hills.

Messrs. Skeats and Summers also refer to Emu Creek, a locality to the north-east of the area discussed in this paper. They state:[36] "On the Emu Creek in Allot. 48a, Parish of Kerrie, another find of graptolites was made; Dr. Hall identified *Diplograptus foliaceus* and *Dicellograptus elegans*. The beds dipped at a high angle downstream in a south-easterly direction, and again the Kerrie Conglomerate occurs only to the west and north-west of these beds. A short distance upstream from the point where the graptolites occur the conglomerates occur in situ dipping downstream, and conformable with sandstones overlying them. Above this shales come in and further upstream conglomerates

33. 4, p. 45.
34. Ibid. p. 14.
35. 4, p. 41.
36. 4, p. 41.

once more appear in force." They add[37] that "it would be possible to regard the conglomerates as unconformably and overlying the Upper Ordovician shales, or as being conformable and underlying the beds which contain the graptolites." They adopt as the more probable view "that there is one marked band of conglomerate repeated in Emu Creek by faulting or folding, and that it underlies the Upper Ordovician shales. Probably it forms the basal member of that series, and rests unconformably upon the Lower Ordovician series." At two localities where we observed the conglomerate coming almost to the water's edge in Emu Creek, it seemed to us to rest upon the upturned edges of shales, almost certainly the same as those which further downstream yield Upper Ordovician graptolites. At the second outcrop the shales were so nearly in contact with the conglomerate that we tried, though unsuccessfully, to clear the loose boulders and expose the junction. Our conclusion is that at Emu Creek, as at Riddell's Creek, the Kerrie Conglomerate is younger than Upper Ordovician graptolite shales.

(b) Age of the Kerrie Conglomerate.

The Conglomerate has been stated to consist of rounded boulders and pebbles of quartzite, and it would be difficult to imagine a more unpromising rock in which to search for fossils. That fossils occurred in it seemed at first probable, since Ba 73, near the mouth of Conglomerate Creek, refers to "a pebble from the conglomerate." It soon appeared that this fossil was most likely obtained from the Grits, which outcrop at this spot, but which were not recognised by the Geological Survey. In spite of the unpromising nature of the Conglomerate, we were successful in finding fossils in it. In fact, west of Conglomerate Creek, loose boulders of Conglomerate can be obtained which would be mistaken for Grit were it not that the matrix is shown in many instances. The fossils are the same brachiopod and crinoid fragments, and it seems probable that the Conglomerate here is composed partly of waterworn pebbles from the Riddell Grits. Pebbles can be obtained from the Conglomerate, which show every gradation of fineness shown by the Grits. Elsewhere the Conglomerate seems to have been derived mainly from the quartzose bands of the Upper Ordovician.

37. Op. cit. p. 42.